

**TRANSMITTAL LETTER TO THE UNITED STATES
DESIGNATED/ELECTED OFFICE (DO/EO/US)
CONCERNING A FILING UNDER 35 U.S.C. 371**

37637-0008

U.S. APPLICATION NO. (If known, see 37 C.F.R. 1.51)

10/019230

INTERNATIONAL APPLICATION NO.
PCT/EP00/06202

INTERNATIONAL FILING DATE
3 July 2000 (03.07.2000)

PRIORITY DATE CLAIMED
1 July 1999 (01.07.1999)

TITLE OF INVENTION

THERMOSETTING PLASTICS AS SUBSTRATE MATERIALS FOR OPTICAL SYSTEMS

APPLICANT(S) FOR DO/EO/US

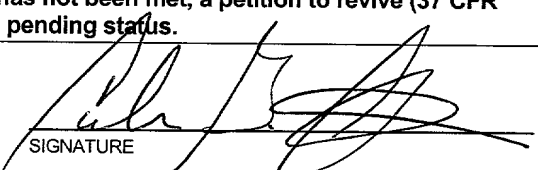

Monika BAUER, Joerg BAUER, Christian DREYER, Norbert KEIL, and Crispin ZAWADZKI

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a FIRST submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a SECOND or SUBSEQUENT submission of items concerning a filing under 35 U.S.C. 371.
3. ☐ This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371©(2))
 - a. ☒ is transmitted herewith (required only if not transmitted by the International Bureau).
 - b. ☐ has been transmitted by the International Bureau.
 - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US)
6. ☐ A translation of the International Application into English (35 U.S.C. 371 ©(2)).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371©(3))
 - a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
 - b. ☐ have been transmitted by the International Bureau.
 - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
 - d. ☒ have not been made and will not be made.
8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371©(3)).
9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371©(4)).
10. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371©(5)).

Items 11. to 16. below concern other document(s) or information included:

11. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☐ A FIRST preliminary amendment.
☐ A SECOND or SUBSEQUENT preliminary amendment.
14. ☐ A substitute specification.
15. ☐ A change of power of attorney and/or address letter.
16. ☒ Other items or information:
 - (i) Copy of Form PCT/IB/306

U.S. APPLICATION NO. (If known, see 37 C.F.R. 1.50) 10/019230		INTERNATIONAL APPLICATION NO PCT/EP00/06202		ATTORNEY'S DOCKET NUMBER 37637-0008																										
17. <input checked="" type="checkbox"/> The following fees are submitted:				CALCULATIONS <small>PTO USE ONLY</small>																										
Basic National Fee (37 CFR 1.492(a)(1)-(5): Neither international preliminary examination fee (CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO..... \$1040.00 International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO..... \$890.00 International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO..... \$740.00 International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4)..... \$710.00 International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4)..... \$100.00																														
ENTER APPROPRIATE BASIC FEE AMOUNT =																														
Surcharge of \$130.00 for furnishing the oath or declaration later than 20 ____ 30 ____ months from the earliest claimed priority date (37 CFR 1.492(e))																														
<table border="1" style="width:100%; border-collapse: collapse;"> <thead> <tr> <th style="width:15%;">CLAIMS</th> <th style="width:15%;">NUMBER FILED</th> <th style="width:15%;">NUMBER EXTRA</th> <th style="width:15%;">RATE</th> <th style="width:10%;"></th> </tr> </thead> <tbody> <tr> <td>Total Claims</td> <td>____ - 20 =</td> <td>____</td> <td>X \$18.00</td> <td>\$</td> </tr> <tr> <td>Independent Claims</td> <td>____ - 3 =</td> <td>____</td> <td>X \$84.00</td> <td>\$</td> </tr> <tr> <td colspan="3">MULTIPLE DEPENDENT CLAIM(S) (if applicable)</td> <td>+ \$280.00</td> <td>\$</td> </tr> <tr> <td colspan="4" style="text-align: right;">TOTAL OF ABOVE CALCULATIONS =</td> <td>\$890.00</td> </tr> </tbody> </table>						CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		Total Claims	____ - 20 =	____	X \$18.00	\$	Independent Claims	____ - 3 =	____	X \$84.00	\$	MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+ \$280.00	\$	TOTAL OF ABOVE CALCULATIONS =				\$890.00
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Applicants claim small entity status. See 37 CFR 1.27. The fees indicated above are reduced by 1/2.																														
SUBTOTAL =				\$890.00																										
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Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). \$40.00 per property +				+	\$																									
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				charged:	\$																									
<p>a. <input checked="" type="checkbox"/> A check in the amount of <u>\$890.00</u> to cover the above fees is enclosed.</p> <p>b. ____ Please charge my Deposit Account No. <u>08-1641</u> in the amount of \$ ____ to the above fees. A duplicate copy of this sheet is enclosed.</p> <p>c. <input checked="" type="checkbox"/> The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. <u>08-1641</u>. A duplicate copy of this sheet is enclosed.</p>																														
<p>NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.</p>																														
<div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p>SEND ALL CORRESPONDENCE TO:</p> <p>Customer ID No. 26633</p> <p>Colin G. Sandercock</p> <p>HELLER EHRMAN WHITE & MCAULIFFE, LLP</p> <p>1666 K Street, NW, Suite 300</p> <p>Washington, DC 20006</p> <p>Tel: (202) 912-2000</p> <p>Fax: (202) 912-2020</p> </div> <div style="width: 45%; text-align: center;">  <p>SIGNATURE</p> <p>NAME: COLIN G. SANDERCOCK</p> <p>REGISTRATION NUMBER: 31,298</p> <p>DATE: DECEMBER 28, 2001</p> </div> </div> <div style="text-align: center; margin-top: 20px;">  <p>26633</p> </div>																														

10/01/2001

10/01/2001

FEE TRANSMITTAL for FY 2002

Patent fees are subject to annual revision.

Complete if Known

Application Number Not yet assigned

Filing Date December 28, 2001

First Named Inventor Monika BAUER

Examiner Name Unassigned

Group / Art Unit Unassigned

Attorney Docket No 37637-0008

26633

PATENT TRADEMARK OFFICE

TOTAL AMOUNT OF PAYMENT (\$ 890

METHOD OF PAYMENT (check one)

1. ☐ The Commissioner is hereby authorized to charge indicated fees and credit any over payments to:

Deposit
Account
Number

08-1641

Deposit
Account
Name

Heller Ehrman White & McAuliffe LLP

☒ Charge Any Additional Fee Required
Under 37 CFR 1.16 and 1.17

☐ Applicant claims small entity status.
See 37 CFR 1.27

2. ☒ Payment Enclosed:

☒ Check ☐ Credit card ☐ Money
Order ☐ Other

FEE CALCULATION

1. BASIC FILING FEE

Large Fee Code	Entity Fee (\$)	Small Fee Code	Entity Fee (\$)	Fee Description	Fee Paid
101	740	201	370	Utility filing fee	
106	330	206	165	Design filing fee	
107	510	207	255	Plant filing fee	
108	740	208	370	Reissue filing fee	
114	160	214	80	Provisional filing fee	

SUBTOTAL (1)

(\$ 0

2. EXTRA CLAIM FEES

Total Claims	-20 **	=	0	X	Fee from below	=	0
Independent Claims	-3 **	=	0	X	Fee from below	=	0
Multiple Dependent		=		X	Fee from below	=	0

Large Fee Code	Entity Fee (\$)	Small Fee Code	Entity Fee (\$)	Fee Description
103	18	203	9	Claims in excess of 20
102	84	202	42	Independent claims in excess of 3
104	280	204	140	Multiple dependent claim, if not paid
109	84	209	42	** Reissue independent claims over original patent
110	18	210	9	** Reissue claims in excess of 20 and over original patent

SUBTOTAL (2)

(\$ 0

**or number previously paid, if greater, For Reissues, see above

FEE CALCULATION (continued)

3. ADDITIONAL FEES

Large Fee Code	Entity Fee (\$)	Small Fee Code	Entity Fee (\$)	Fee Description	Fee Paid
105	130	205	65	Surcharge - late filing fee or oath	
127	50	227	25	Surcharge - late provisional filing fee or cover sheet	
139	130	139	130	Non-English specification	
147	2,520	147	2,520	For filing a request for reexamination	
112	920*	112	920*	Requesting publication of SIR prior to Examiner action	
113	1,840*	113	1,840*	Requesting publication of SIR after Examiner action	
115	110	215	55	Extension for reply within first month	
116	400	216	200	Extension for reply within second month	
117	920	217	460	Extension for reply within third month	
118	1,440	218	720	Extension for reply within fourth month	
128	1,960	228	980	Extension for reply within fifth month	
119	320	219	160	Notice of Appeal	
120	320	220	160	Filing a brief in support of an appeal	
121	280	221	140	Request for oral hearing	
138	1,510	138	1,510	Petition to institute a public use proceeding	
140	110	240	55	Petition to revive - unavoidable	
141	1,280	241	640	Petition to revive - unintentional	
142	1,280	242	640	Utility issue fee (or reissue)	
143	460	243	230	Design issue fee	
144	620	244	310	Plant issue fee	
122	130	122	130	Petitions to the Commissioner	
123	50	123	50	Processing fee under 37 CFR 1.17 (q)	
126	180	126	180	Submission of Information Disclosure Stmt	
581	40	581	40	Recording each patent assignment per property (times number of properties)	
146	740	246	370	Filing a submission after final rejection (37 CFR § 1.129(a))	
149	740	249	370	For each additional invention to be examined (37 CFR § 1.129(b))	
179	740	279	370	Request for Continued Examination (RCE)	
169	900	169	900	Request for expedited examination of a design application	

Other fee (specify) Basic National Fee

890

*Reduced by Basic Filing Fee Paid

SUBTOTAL (3)

(\$ 890

SUBMITTED BY

Complete (if applicable)

Name (Print/Type)

Colin G. Sandercock

Registration No. Attorney/Agent)

31,298

Telephone

(202) 912-2000

Signature

Date

December 28, 2001

WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.

Burden Hour Statement: This form is estimated to take 0.2 hours to complete. Time will vary depending upon the needs of the individual case. Any comments on the amount of time you are required to complete this form should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, Washington, DC 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Assistant Commissioner for Patents, Washington, DC 20231.

#5

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Attorney Docket No. 37637-0008

Applicant: Monika BAUER et al. Group Art Unit: Unassigned
Appl. No.: 10/019,230 Confirmation No.: Unassigned
Filing Date: December 28, 2001 Examiner: Unassigned
Title: THERMOSETTING PLASTICS AS SUBSTRATE MATERIALS FOR
OPTICAL SYSTEMS

PRELIMINARY AMENDMENT

Commissioner for Patents
United States Patent and Trademark Office
Washington, D.C. 20231

Sir:

Prior to examination of the above-captioned case, applicant respectfully requests entry of the following amendments to the specification and claims.

IN THE SPECIFICATION

Please insert the following centered heading on page 1, line 3, after the Application

Title:

--FIELD OF INVENTION--

Please insert the following centered heading on page 1, line 9:

--BACKGROUND OF INVENTION--

10019230 022801

Please insert the following centered headings and paragraphs on page 4, after line 29:

--SUMMARY OF THE INVENTION

The present invention relates an optical system comprising a substrate material and at least one optical element, wherein the substrate comprises a thermoset plastic selected from the group consisting of polycyanurate resins, polycyanate resins, epoxy resins, bismaleimide resins, bismaleimide triazine resins, and mixtures thereof. The present invention also relates to a process of preparing such optical systems.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows an open casting mould for the preparation of substrates according to the present invention.

Figure 2 shows a sealed mould for the preparation of substrates according to the present invention.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT--

IN THE CLAIMS

Please cancel claims 1-24 without prejudice or disclaimer.

Please add the following new claims:

25. (New) An optical system comprising a substrate and at least one optical element applied thereto, said substrate comprising a thermosetting plastic, wherein the thermosetting plastic comprises a material selected from the group consisting of polycyanurate resins, polycyanate resins, and mixtures of polycyanurate resins and polycyanate resins.

26. (New) The optical system according to claim 25, wherein the thermosetting plastic further comprises at least one of epoxy resins, bismaleimide resins, or bismaleimide triazine resins.

27. (New) The optical system according to claim 25, wherein the thermosetting plastic has a glass transition temperature of not less than 150°C.

28. (New) The optical system according to claim 27, wherein the thermosetting plastic has a glass transition temperature of not less than 200°C.

29. (New) The optical system according to claim 28, wherein the thermosetting plastic has a glass transition temperature of not less than 250°C.

30. (New) The optical system according to claim 29, wherein the thermosetting plastic has a glass transition temperature of not less than 300°C.

31. (New) The optical system according to claim 25, wherein the substrate additionally comprises a thermoplastic material and/or an elastomeric material.

32. (New) The optical system according to claim 31, wherein the elastomeric material is selected from the group consisting of acrylonitrile-butadiene, acrylonitrile-butadiene-styrene, polyesters and polyurethanes.

33. (New) The optical system according to claim 31, wherein the thermoplastic material is selected from the group consisting of polyimides, polyetherimides, polyethersulfones, polysulfones, polyarylates, polycarbonates, polyesters, and mixtures thereof.

34. (New) The optical system according to claim 25, wherein the substrate additionally comprises at least one material having a thermal conductivity that is higher than the thermal conductivity of said thermosetting plastic.

35. (New) The optical system according to claim 34, wherein the material having a higher thermal conductivity than said thermosetting plastic is selected from the group consisting of metals, alloys, carbon black, and graphite.

36. (New) The optical system according to claim 35, wherein the material having a higher thermal conductivity than said thermosetting plastic is selected from the group consisting of silver, copper, and mixtures of silver and copper.

37. (New) The optical system according to claim 34, wherein the material having a higher thermal conductivity is incorporated into the thermosetting plastic in the form of a powder, a granulate, of flakes or of woven or non-woven textiles.

38. (New) The optical system according to claim 34, wherein the substrate includes restricted areas wherein the material having a higher thermal conductivity is only incorporated into the thermosetting plastic in restricted areas of the substrate.

39. (New) The optical system according to claim 25, wherein the substrate additionally comprises at least one material which is capable of lowering the coefficient of thermal expansion of the thermosetting plastic.

40. (New) The optical system according to claim 39, wherein the material which lowers the coefficient of thermal expansion of the thermosetting plastic is selected from the group consisting of glass, ceramics, metal, graphite and carbon black.

41. (New) The optical system according to claim 25, wherein the optical system is a waveguide system, an electro-optical actuator or a thermo-optical actuator.

42. (New) The optical system according to claim 25, wherein the at least one optical element is prepared from or prepared using an organic polycyanate and/or polyperfluorocyclobutane.

43. (New) The optical system according to claim 42, wherein the organic polycyanate is a (co)polymerisate of at least one aromatic dicyanate.

44. (New) The optical system according to claim 43, wherein the organic polycyanate is a (co)polymerisate of a fluor-free aromatic dicyanate and a fluor-containing aromatic dicyanate.

45. (New) A process for the preparation of a substrate for an optical system according to claim 25 comprising casting a liquid which upon curing forms a thermosetting plastic into a casting mould, optionally sealing the casting mould, optionally degassing the resin by applying a vacuum, and curing the resin by applying a suitable temperature or temperature profile.

46. (New) The process according to claim 45, wherein at least one of (i) a material having a higher thermal conductivity than said thermosetting plastic, (ii) a thermoplastic material, (iii) an elastomeric material, and (iv) a material that lowers the coefficient of thermal expansion of the thermosetting plastic, is added to the liquid.

47. (New) The process according to claim 45, wherein a material that is capable of lowering the coefficient of thermal expansion of the thermosetting plastic is added to the resin, which upon curing, will form a thermosetting plastic.

48. (New) The process according to claim 47, wherein the material is selected from the group consisting of glass, ceramics, metal, graphite and carbon black.

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49. (New) The process according to claim 46, wherein the said at least one material (i)-(iv) is added to said liquid by placing said material only into predetermined restricted areas of said casting mould.

50. (New) The process according to claim 46, wherein the material is added after the liquid has been brought into the casting mould.

51. (New) The process according to claim 50, wherein the material is added only into predetermined restricted areas of said casting mould.

10019230.032302

REMARKS

Applicants respectfully request that the foregoing amendments be made prior to examination of the present application. Please cancel claims 1-24 without prejudice or disclaimer and add new claims 25-51. Accordingly, claims 25-51 are pending. No new matter has been added.

A first office action on the merits is awaited. Please direct all correspondence to the undersigned attorney or agent at the address indicated below.

Respectfully submitted,

March 28, 2002

Date

Susan E. Phan McBeck

for Colin G. Sandercock
Reg. No. 31,298

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Washington, DC 20006
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26633

PATENT TRADEMARK OFFICE

Thermosetting plastics as substrate materials for optical systems

The present invention is directed to optical instruments and systems, e.g. wave guides or wave guide systems, which comprise organic polymers as optical elements, applied to suitable substrates. Specifically, the substrates consist of or comprise thermosetting plastics.

Organic polymers are increasingly interesting materials in the optical or microoptical field, in integrated optics or in microsystem techniques. In these fields, they may be used in optical instruments and apparatuses or parts thereof as well as in special optics as lenses, prisms, for fixation of optical systems, as support material for optical layers and as translucent coating materials for mirrors or lenses. Organic polymers may be used in optical fibres and for the preparation of waveguide structures. Their technical handling is relatively easy, and their density is lower in comparison to glass.

Specifically, if different optical elements are to be integrated on a chip, e.g. of electro-optical or thermo-optical actuators or arrayed waveguide gratings (AWGs), respectively, a variety of requirements of the overall system polymer/substrate have to be met. Most important are the optical properties, for example refractive index and optical losses of the materials, but also technological requirements like preparation of layers and structurability as well as the thermal and thermo-mechanical stability and the long-term retention of all important parameters. For a variety of optical elements, specific requirements have to be met in addition, for example low birefringence (especially in AWGs) or variability of the refractive index by means of a circuit using applied electrodes (electro-optical and thermo-optical actuators). Especially if switching is performed thermo-optically, the thermoconductivity of the overall system polymer/substrate plays an important role for the quality of the optical element. If multiple optical elements are combined on a substrate, all requirements have to

be fulfilled for each element and each of the combinations of elements/substrates. This is very difficult.

Until now, polymethacrylates and polycarbonates have been mainly used for optical purposes. Both classes of polymers have an excellent light transmittance, but their thermal and thermo-mechanical stability is not sufficient due to their chemical structure. Thus, polymethacrylates and polycarbonates cannot practically be used at temperatures exceeding 130°C which is due to their relatively low glass transition temperatures. In addition, both types of polymers are linear, un-crosslinked polymers. This has the adverse effect that they are partly solubilized in case multilayer-systems are prepared via the application of dissolved components, e.g. by spin-coating each layer. Consequently, the layer structures as obtained are not sufficiently delimited and neat which, however, is an essential for the preparation of waveguide structures.

Increasingly used are other high performance polymers which have glass transition temperatures of more than 180°C. Examples are polyarylethersulfones, polyarylsulfones, polyaryletherketones, polyimides and polyetherimides, the processing of which, however, is more difficult than that of polymethacrylates and polycarbonates. However, they suffer from the disadvantage of relatively high optical attenuation at 1.3 μm and 1.55 μm , wavelengths which are important in communication engineering technologies.

Polyperfluorocyclobutanes (PFCB) are a relatively new class of high performance polymers. Upon thermal curing they yield unsoluble cross-linked polymers which are characterized by high thermal stability. Waveguide layers prepared from PFCB show very low optical losses of 0.2 dB/cm at 1550 nm.

Also, polycyanurates have been used for the preparation of optical components. US patents 5 208 892 and 5 165 959 describe the preparation of polycyanate resins made of a single monomer (either fluorinated or non-fluorinated). German

Offenlegungsschrift DE 44 35 992 A1 describes optical elements prepared from polycyanurate resins. Like polyperfluorocyclobutanes, polycyanurates yield unsoluble cross-linked polymers upon thermal curing, and these polymers are as well characterized by high thermal stability. They are specifically useful due to their excellent adhesional force on a variety of substrates, for example silicon, silica or a variety of organic polymers. Refractive index and glass transition temperature of the cured cross-linked polymers may be varied in broad ranges, due to the easy availability of a great number of di- and mono-functional cyanate monomers which may be copolymerized with each other. Completely cured polycyanurates known in the art which consequently are stable for long terms may have optical losses of about 0.2 dB/cm at 1.3 μ m, but not less than 0.5dB/cm at 1.55 μ m.

Specifically in case cross-linked polymers having high glass transition temperatures are used for the preparation of the optical systems to be prepared, a variety of preparation steps have to be performed at high temperatures. For example, curing of polycyanurate layers is performed at 200° to 250°C, and that of PFCB layers at 240° to 300°C. On the other hand, use of the optical systems thus prepared is in general from environmental temperature to about 80°C. If the coefficients of thermal expansion of the substrate and of the polymer layers differ from each other, for example if silicon wafers are used for the substrate, a thermal stress is developed in the layers during the repeated heating and cooling operations which result in an enormous optical birefringence or, in the worst case, in a rupture or scaling of the optical layer(s) from the substrate.

In US patent 5,170,461 to Yoon et al., the preparation of thermoplastic polymer substrates for use in organopolymer electro-optical wave guides is described. The polymer substrate is fabricated using sufficiently stress-free thermoplastic transformation, e.g. injection moulding or compression moulding. As the materials, commercially available thermoplastics like polycarbonates, polyacrylates, polysulfones, polyimides and the

like are used. Onto these substrates, polymer layers are applied according to known techniques, yielding wave guide structures. The polymeres used for the optical systems show coefficients of thermal expansion which are similar to those of the substrates used by which optical systems having low stresses frozen therein and consequently having a low birefringence are obtained.

If cross-linked polymers having a high glass transition temperature are used for the preparation of the optical elements, thermoplastic substrates cannot be used in most cases. First, the substrate softens and is deformed when the layers are cured at the required high temperatures of about 200 to 300°C because thermoplastic materials in general show a too low thermostability. Second, the coefficients of thermal expansion of thermoplastic materials are usually in a range of 100 ppm higher than those of cross-linked polymers (in general about 60 ppm), resulting in the inclusion of stresses and consequently in an undesired optical birefringence at the working temperature of the optical element or system. In this regard, substrates made of thermoplastics are comparable to substrates made of silicon. Third, unmodified, e.g. thermoplastic polymer substrates for e.g. thermo-optical actuators suffer from a very low thermal conductivity which results in unfavourable temperature profiles and consequently in a bad rupturing performance. If different optical elements are to be placed on the same chip, e.g. AWGs and thermo-optical actuators, it is therefore not possible to realise an optimum layer construction for all elements.

The present invention provides thermal and thermo-mechanical long-term substrates for optical elements or systems, which have coefficients of thermal expansion adaptable to those of the optical elements. The substrates of the invention contain or consist of thermosetting plastics and have duromeric properties.

Preferably, the thermosetting plastics are selected from epoxyd resins, polycyanurate resins, polycyanate resins, bismaleimide resins and bismaleimide triazine resins or mixtures thereof.

Polycyanurate resins, polycyanate resins, or mixtures thereof are preferred. They may e.g. be prepared from resins ("reactive resins") selected from the group comprising epoxides (e.g. Araldit LY 556 from Ciba Speciality Chemicals Inc),
5 polycyanurates or polycyanates (e.g. AroCy B-10 from Lonza AG),
bismaleimides (e.g. Compimide 796 from Technochemie),
bismaleimide triazine resins (e.g. BT2400 from Mitsubishi Gas Chemical Comp., Inc.) and the like or mixtures of such resins which partly are commercially available and partly known from
10 the literature.

In one embodiment of the invention, substrates are provided which have at least partly an increased thermal conductivity, compared to usual organic polymers as mentioned above, in order
15 to provide substrates which may be used to carry parts of AWG's like thermo-optical actuators or the like for which a suitable thermal conductivity of the substrate is required. In this case, the substrates contain or consist of a thermosetting plastic in combination with a material having a higher thermal conductivity
20 than said thermosetting plastic.

In an specific embodiment, the invention provides a substrate having different thermal conductivity in different parts of the substrate.
25

Usually, the substrates are easy to prepare and can be polished, and the application and processability of polymer layers onto the substrates in order to provide optical elements or systems, e.g. wave guide structures, is possible according to common
30 methods.

In cured condition, the thermosetting plastics used according to the invention are duromers and show glass transition temperatures which exceed the temperatures required for
35 application of the optical layers to be applied thereon during preparation of the optical systems. Preferably, they are in a range of 150 - 350°C, more preferable not less than 200°C.

The substrates of the optical systems according to the present invention can be prepared by casting, preferably by curing the respective reactive resins in a casting mould. Injection moulding or compression moulding should be avoided. Casting moulds may be open or sealed.

Figure 1 shows an open casting mould for the preparation of substrates according to the present invention. The reference numbers are as follows: On an adjustable ground-plate 1, a PTFE-plate 2 and a steel-plate 3 are locked together with lockings 4 and 4'. The diameter d of the mould may be e.g. 3" (7,62 cm). The thickness of the mould may be about 1 mm.

Figure 2 shows a sealed mould for the preparation of substrates according to the present invention. On a ground-plate 1, two aluminum-plates 2 are mounted which are spaced by an PTFE-distance holder 3. The aluminum-plates and the distance holder are connected by locking screws 4. The inside dimension may be e.g. 10 cm x 20 cm x 2 mm.

For the preparation of the substrate of the invention, the uncured resin (if necessary after liquefification by applying sufficient heat) is casted into a suitable mould. If necessary or favorable, a vacuum or a reduced pressure is applied, e.g. using a vacuum drying oven. Subsequently, the resin is cured using a suitable temperature or temperature profile. Not more but very little mechanical stress in the moulded articles is obtained by low cooling of the moulds until environmental temperature is reached. After demoulding, the obtained substrates may be mechanically treated or machined, e.g. cut, sawed, milled or sinked. In accordance to the requirements of the surface to be met in order to ensure correct application of the optical layers, the surface may be polished using common methods which are e.g. known from the technology of silicon wafers.

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The coefficient of thermal expansion of the substrate may be adapted to that of the optical element(s) or layer(s) applied thereon in different ways. First, it is possible to mix more than one of the "reactive" resins (i.e. those which upon curing would yield duromers) having different coefficients of thermal expansion. By this way, a thermosetting plastic having the desired value thereof may be obtained. Further, the resins of the present invention yielding thermosetting plastics may be mixed with thermoplastic materials. The thermoplastic materials are preferably selected from polyimides (e.g. Matrimid 5218 from Ciba Speciality Chemicals Inc.), polyetherimides (e.g. Ultem[®] 1000 from General Electric), polyethersulfones (e.g. Victrex[®] 5003P from ICI), polysulfones (e.g. Udel[®] 1800P from Amoco), polyarylates (e.g. Ardel[®] D100 from Amoco), polycarbonates (e.g. Merlon[®] from General Electric), polyesters (e.g. Vitel 3200 from Bostik). Alternatively or in addition, the thermosetting plastics may be mixed with elastomeres, e.g. Hycar[®] HTBN or Hycar[®] ATBN from BF Goodrich, polytetrahydrofuran (e.g. CD 2000 from BASF), or polyurethane (e.g. Desmodur E23 from Bayer AG). Both kinds of additives result in an increase of the coefficient of thermal expansion. If mixtures are used which do not show a macroscopic phase separation, the ratio of thermosetting plastics and thermoplastic material/elastomeric material may be selected as desired, thereby allowing to adjust the coefficient of thermal expansion as needed in the whole range between that of the thermosetting plastic and that of the thermoplastic/elastomeric material. Of course, the ratio of thermoplastic material has to be chosen in such a way that the duromeric properties of the substrate is maintained. Preferably, the thermosetting plastic is present in the mixture in an amount of at least about 30% by weight, more preferably of at least about 50% per weight.

On the other hand, if the coefficient of thermal expansion shall be lowered, this may be obtained by mixing the thermosetting plastic(s) with materials like glass, ceramics, metal, graphite, carbon black and/or others which may be incorporated as powders, woven or non-woven textiles, e.g. fleeces or webs. If sufficient

thermosetting plastic is used as a binder between these additional elements, the strength of the substrate is satisfactory. In order to obtain such a strength, preferably at least 5 wt.-% and more preferably more than 50 - 99 wt.-% of the thermosetting plastic is used in this mixture. Due to the broad range of mixing ratio, the coefficient of thermal expansion may be adjusted as required in the whole range between that of that of the thermosetting plastic and that of the filling material.

To increase the thermal conductivity of the substrate, the thermosetting plastic can be mixed with materials like metals or alloys, e.g. copper, silver, or any other suitable metal having a good thermal conductivity, carbon black, graphite and others. Again, such substances may be used as powders, granules, flakes, woven or non-woven textiles (fleeces) and the like.

In order to maintain a sufficient strength of the substrate, preferably more than 20-50 wt.-% of the thermosetting plastic is used in this mixture.

In addition to the thermal conductivity varying substance(s), thermoplastic or elastomeric material can be incorporated into the mixture. Thus, the coefficient of thermal expansion may be adjusted together with that of the thermal conductivity, as desired.

In a specific embodiment, a substrate is provided having different coefficients of thermal expansion and/or thermal conductivity in different areas of the substrate, the latter being preferred. Such substrates may be obtained by a partial modification of the materials used for the substrate as described above, but only in specific areas of the substrate. Preferably, the resin is cured in an open mould (see figure 1). Materials like those exemplified above for the respective modification are applied into the desired specific areas of this mould as required. These materials may have the form of powders, flakes, granules, woven or non-woven textiles and the like. If thermoplastic or elastomeric materials as described above shall

be introduced, this may be done using high viscous molten charges. Alternatively or in addition, molten charges of thermoplastic or elastomeric materials may be used into which a suitable powder has been suspended. This embodiment may be used if fixation of the powder (e.g. one of those mentioned above) at specified areas is desired. After introduction of the materials as described above, the mould is filled with resin which upon curing yields a thermosetting material. After curing of the substances present in the mould, a substrate having areas of different coefficient of thermal expansion and/or of thermal conductivity is obtained.

The invention is now further illustrated by way of examples:

Example 1

6g AroCy® B-10 (Lonza AG) are heated to 90°C in a round bottomed flask and the melted material is degassed at 2-3 kPa for 30 min. The melt is poured into a casting mould as shown in figure 1, having an inner diameter d of 3" (7,62 cm) and a thickness of about 1 mm. Subsequently, the mould is brought into a drying oven in order to cure the resin. The temperature profile applied is: 20 h at 180°C, 30 min to reach 200°C, 1h at 200°C, 30 min to reach 220°C, 1 h at 220°C, 30 min to reach 240°C, 1 h at 240°C, 30 min to reach 260°C, 1 h at 260°C, 30 min to reach 280°C, 1 h at 280°C, cooling to room temperature with a rate of 0.5 K/min. After releasing the substrate from the mould, the rim is trimmed using abrasive paper, and a firm, stable disc or plate is obtained, having 3" diameter and a thickness of 1 mm. Then, the already very smooth surface of the disc is polished using fine-grained abrasive.

7.3 g of 2,2'-bis(4-cyanatophenyl) hexafluoropropane and 2.7 g of 2,2'-bis(4-cyanatophenyl) propane are heated to 180 °C in a sealed vessel for a time of about five hours. The reaction is terminated before gelling starts, and a clear, pale yellow prepolymer is obtained which is viscous at 180°C and is solid at room temperature. The prepolymer is brought into solution by

mixing it with 50 % by weight of ethylethoxyacetate. Spin-coating of this solution onto the polymeric substrate described above as well as onto a substrate made of silicon yields layers which can be cured at 240°C for one hour in a drying oven. The layer on the silicon substrate has a birefringence of 0.004 and the layer on the polymeric substrate has a birefringence of 0.0005 at a wavelength of 1.55 μm .

Example 2

5g AroCy® B-10 (Lonza AG) are heated to 90°C in a round bottomed flask and the melted material is degassed at 2-3 kPa for 30 min. The melt is poured into a casting mould as shown in figure 1, having an inner diameter $d=3"$ (7,62 cm) and a thickness of about 1 mm. 1 g of a mixture of 60 wt-% copper powder and 40 wt-% AroCy® L-10 (Lonza AG) are poured to that area in the casting mould in which a different thermal conductivity shall be obtained, compared to the remaining areas of the substrate. Subsequently, the polymer is cured in a drying oven. The temperature profile applied is: 20 h at 180°C, 30 min to reach 200°C, 1h at 200°C, 30 min to reach 220°C, 1 h at 220°C, 30 min to reach 240°C, 1 h at 240°C, 30 min to reach 260°C, 1 h at 260°C, 30 min to reach 280°C, 1 h at 280°C, cooling to room temperature with a rate of 0.5 K/min. After releasing the substrate from the mould, the rim is trimmed using abrasive paper, and a firm, stable disc or plate is obtained, having 3" diameter and a thickness of 1 mm. A delimited area can be seen on the disk which contains the copper powder. Optional, the already very smooth surface of the disc may be polished using fine-grained abrasive. The substrate thus obtained may be used in the preparation of optical systems (e.g. comprising optical multi-layers), for example using processing steps like spin-coating, thermocuring, RIE-etching and the like, as it is known for the processing of silicon wafers.

Example 3

53 g of a mixture of 41.5 wt.-% bisphenol A diglycid ether, 37.5 wt.-% tetrahydrophthalic anhydride, 1 wt.-% dimethylbenzylamine and 20 wt.-% Hycar® HTBN (BF Goodrich) are heated to temperature of 70°C in a round bottomed flask, and the melt is degassed at 2-3 kPa for 30 min. The melt is cast into a sealable casting mould (Figure 2) having inner dimensions of 22x12x0.15 cm and is cured in a drying oven; temperature profile: 5 h at 80°C, 30 min to reach 120°C, 1 h at 120°C, 30 min to reach 140°C, 1 h at 140°C, 30 min to reach 160°C, 1 h at 160°C, and cooling to environment temperature at a rate of 0.5 K/min. After releasing from the mould, a stable plate is obtained. Two discs having a diameter of 4" (10.16 cm) are cut from the plate, using a lead saw. Both surfaces of the disc are polished several times using an abrasive of consecutively finer grains. The substrate thus obtained may be used in the preparation of optical systems (e.g. comprising optical multi-layers), for example using processing steps like spin-coating, thermocuring, RIE-etching and the like, as it is known for the processing of silicon wafers.

* * *

Claims:

1. Use of a thermosetting plastic as a substrate material in optical systems, characterized in that the thermosetting plastic is selected from at least one of the group consisting of polycyanurate resins, polycyanate resins, or mixtures thereof, or of mixtures of these resins with epoxyd resins, bismaleimide resins, and/or bismaleimide triazine resins.
2. Use according to claim 1 or 2, wherein the thermosetting plastic has a glass transition temperature of not less than 150°C, preferably of not less than 200°C, more preferably of not less 250°C and most preferably not less than 300°C.
3. Use according to any of claims 1 or 2, wherein the substrate material additionally contains at least one of a thermoplastic material and an elastomeric material.
4. Use according to claim 3, wherein the thermoplastic material is selected from polyimides, polyetherimides, polyethersulfones, polysulfones, polyarylates, polycarbonates, polyesters and mixtures of these polymers and/or wherein the elastomeric material is selected from acrylonitrile-butadiene, acrylonitrile-butadiene-styrene, polyesters and polyurethanes.
5. Use according to any of the preceding claims, wherein the substrate material additionally contains at least one material having a higher thermal conductivity than said thermosetting plastic.
6. Use according to claim 5 wherein the material having a higher thermal conductivity than said thermosetting plastic is selected from the group of metals or alloys, carbon black, and graphite, and preferably from silver and/or copper.

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7. Use according to claim 5 or 6 wherein the material having a higher thermal conductivity is incorporated into the thermosetting in the form of a powder, a granulate, of flakes or of woven or non-woven textiles.

5 8. Use according to any of claims 5 to 7 wherein the material having a higher thermal conductivity is incorporated into the thermosetting only into restricted areas of the substrate.

10 9. Use according to any of the preceding claims, wherein the substrate material additionally contains at least one material which lowers the coefficient of thermal expansion of the thermosetting plastic, the said material preferably selected from glass, ceramics, metal, graphite and carbon black.

15 10. Use according to claim 1 wherein the optical system is a waveguide system or an electro-optical actuator or a thermo-optical actuator.

20 11. Process for the preparation of a substrate for optical systems, wherein a liquid which upon curing forms a thermosetting plastic as defined in claim 1, is casted into a casting mould, the casting mould is optionally sealed, the resin is optionally degassed by applying a vacuum, and the resin is cured by applying a suitable temperature or temperature profile.

25 12. Process according to claim 11, wherein at least one material, selected from materials having a higher thermal conductivity than said thermosetting plastic, thermoplastic materials, elastomeric materials and materials which lower the coefficient of thermal expansion of the thermosetting plastic, is added to the liquid.

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13. Process according to claim 11 or 12 wherein a material which lowers the coefficient of thermal expansion of the thermosetting plastic is added to the resin which upon curing will form a thermosetting plastic, the said material preferably selected from glass, ceramics, metal, graphite, carbon black.

14. Process according to any of claims 11 or 12 wherein the thermoplastic material and/or the elastomeric material and/or the material which lowers the coefficient of thermal expansion of the thermosetting plastic and/or the material having a higher thermal conductivity is added by placing it only into predetermined restricted areas of the mold.

15. Process according to claim 12, wherein the material is added only after the liquid has been brought into the casting mould, and preferably only into predetermined restricted areas of the said mould.

16. Optical system, comprising a substrate material and at least one optical element applied thereto, wherein the substrate material is a thermosetting plastic, selected from at least one of the group consisting of polycyanurate resins, polycyanate resins, or mixtures thereof, or of mixtures of these resins with epoxyd resins, bismaleimide resins, and/or bismaleimide triazine resins.

17. Optical system according to claim 16 which is an optical waveguide system or an electro-optical actuator or a thermo-optical actuator.

18. Optical system according to claims 16 or 17, wherein the thermosetting plastic has a glass transition temperature of not less than 150°C, preferably of not less than 200°C, more preferably of not less than 250°C, and most preferably not less than 300°C.

19. Optical system according to any of claims 16 to 18, wherein the substrate material consists of the said thermosetting plastic and at least one thermoplastic material, preferably selected from polyimides, polyetherimides, polyethersulfones, polysulfones, polyarylates, polycarbonates, polyesters and mixtures of these polymers, and/or at least one elastomeric material, preferably selected from acrylonitrile-butadiene, acrylonitrile-butadiene-styrene, polyesters and polyurethanes.

20. Optical system according to any of claims 16 to 19, wherein at least one optical element applied to the substrate is prepared from or using an organic polycyanate and/or PFCB.

21. Optical system according to any of claims 16 to 20, wherein at least one optical element applied to the substrate is prepared from or using an organic polycyanate and/or PFCB.

22. Optical system according to claim 21, wherein the organic polycyanate is a (co)polymerisate of at least one aromatic dicyanate.

23. Optical system according to claim 22, wherein the organic polycyanate is a copolymerisate of a fluor-free aromatic dicyanate and a fluor-containing aromatic dicyanate.

* * *

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(54) Title: **THERMOSETTING PLASTICS AS SUBSTRATE MATERIALS FOR OPTICAL SYSTEMS**

(57) Abstract: The present invention relates to the use of a thermosetting plastic as a substrate material in optical systems. The optical system may be e.g. a waveguide system or an electro-optical actuator or a thermo-optical actuator. Preferably the thermosetting plastic is selected from polycyanate resins and polycyanurate resins. It is especially preferred to add a material having higher conductivity to the thermosetting plastic in order to obtain a substrate having an increased thermal conductivity for carrying thermo-optical actuators and the like.



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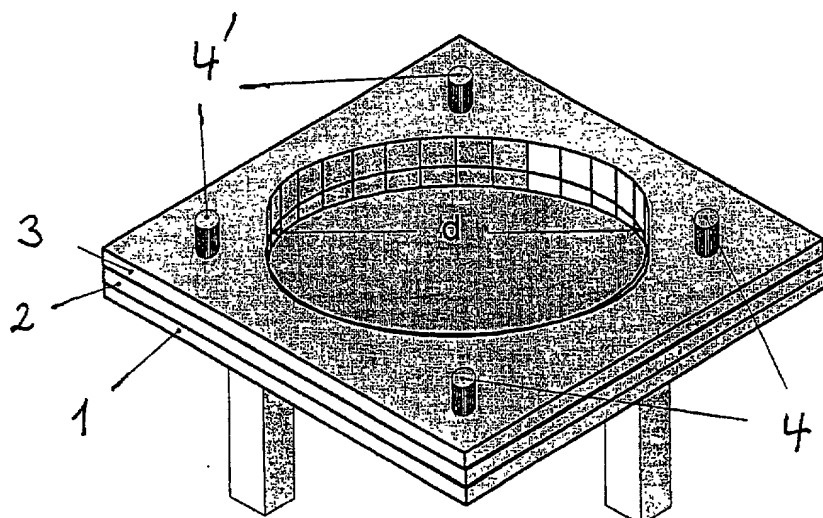


Figure 1

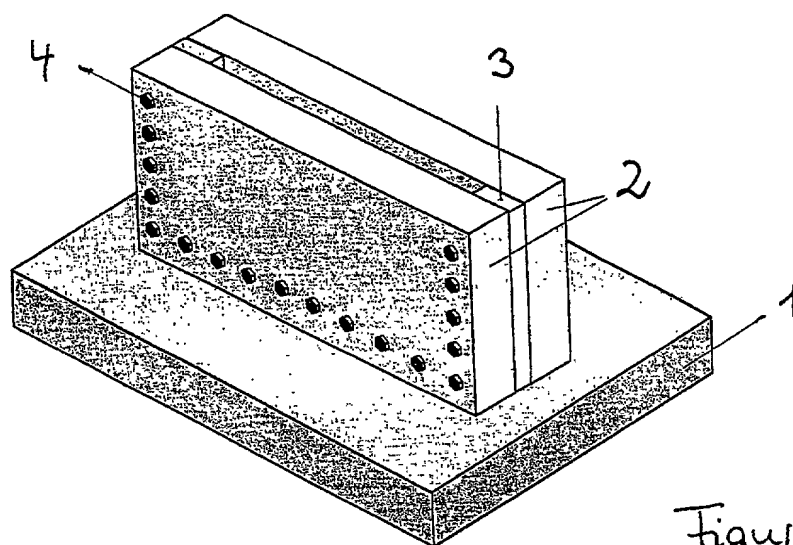


Figure 2

Attorney Docket No.: 37637-0008

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THAT I believe I am the original, first, and sole inventor (if only one inventor is named below) or an original, first, and joint inventor (if plural inventors are named below or in an attached Declaration) of the subject matter which is claimed and for which a patent is sought on the invention entitled

THERMOSETTING PLASTICS AS SUBSTRATE MATERIALS FOR OPTICAL SYSTEMS

the specification of which (check one)

 is attached hereto.

 X was filed on July 3, 2000 as PCT International Application Number PCT/EP00/06202

THAT I do not know and do not believe that the same invention was ever known or used by others in the United States of America, or was patented or described in any printed publication in any country, before I (we) invented it;

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Prior Foreign Application Number	Country	Foreign Filing Date	Priority Claimed?	Certified Copy Attached?
99112602.0	EP	July 1, 1999	Yes	No


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U.S. Provisional Application Number	Filing Date

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3-00

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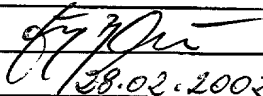
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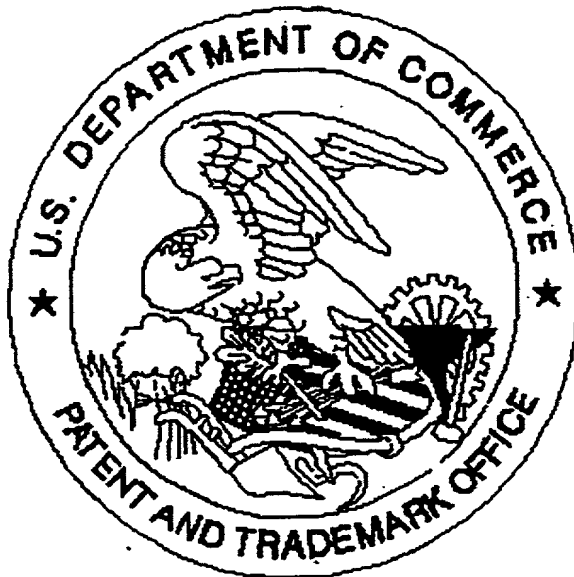
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